LLRF Specs and Topics

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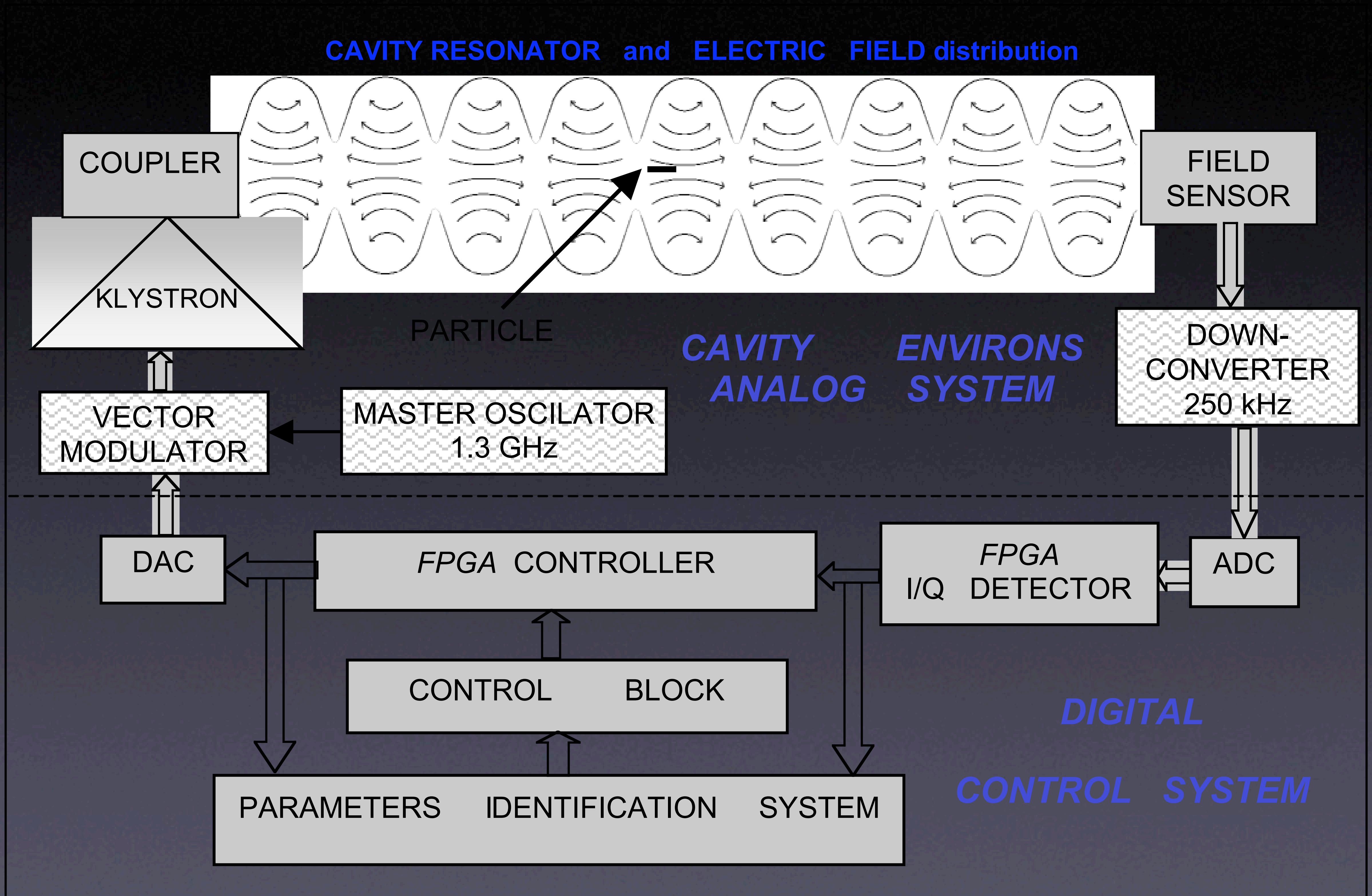
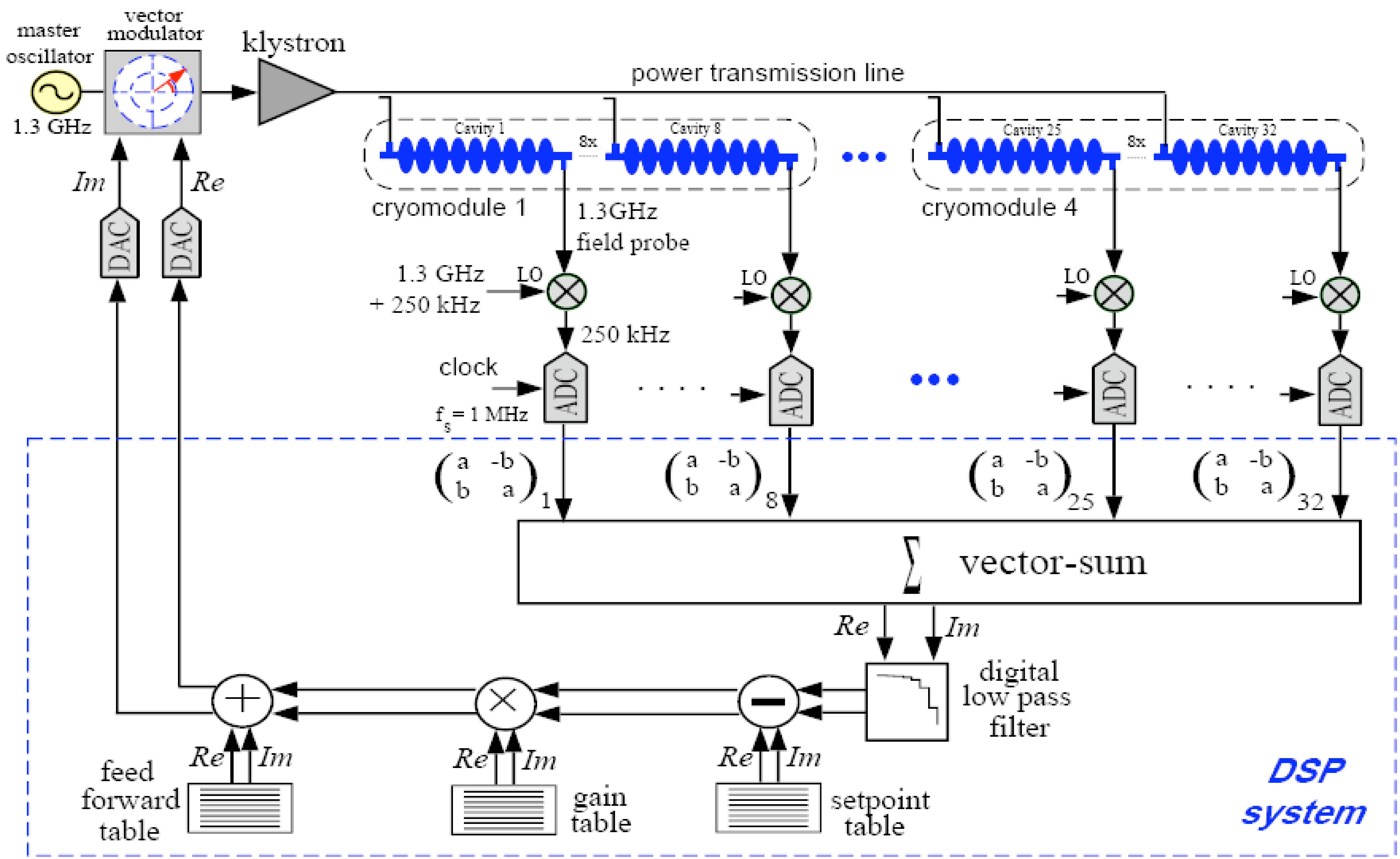
Overview

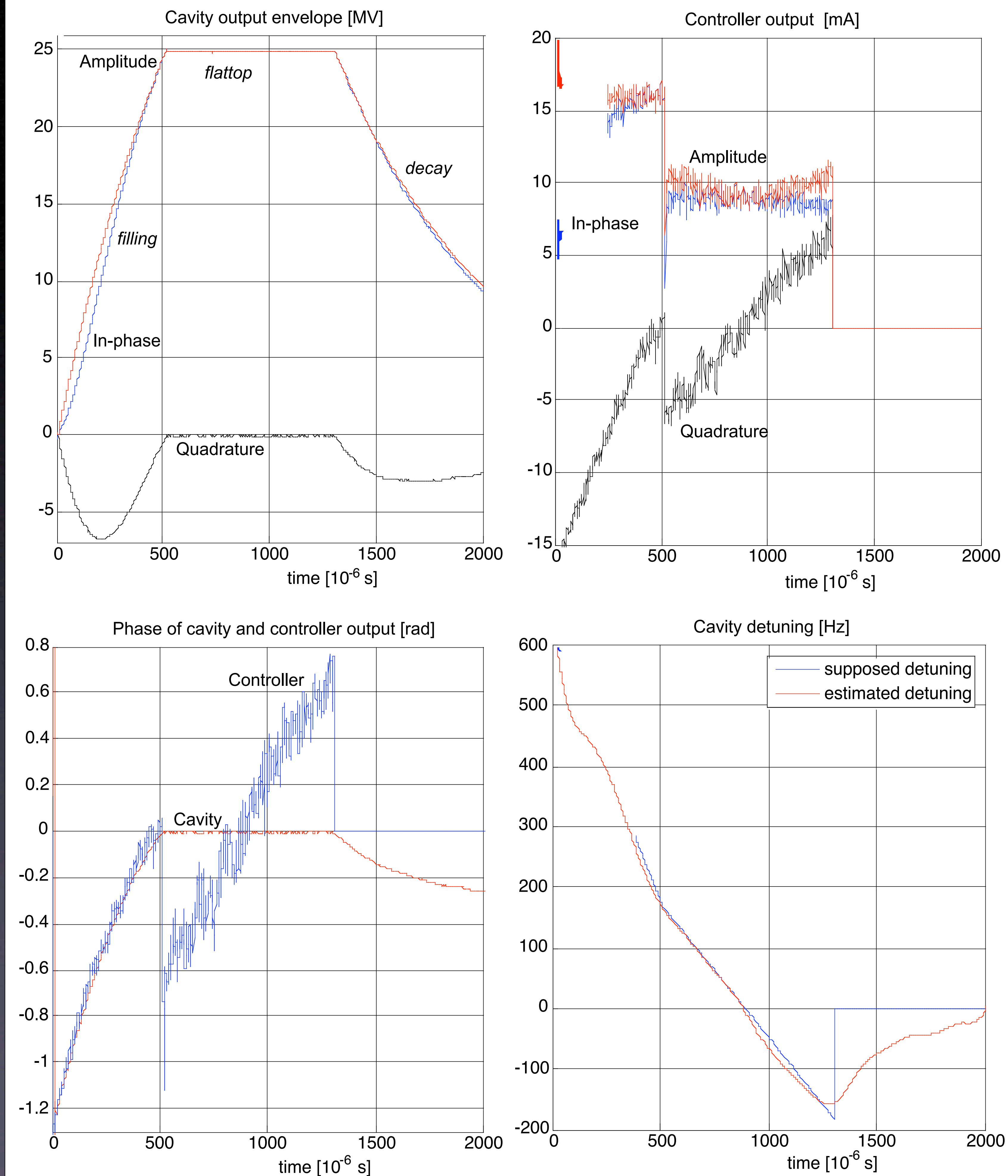
- LLRF as a Servo Loop Controller for the Cavity Field
- Present requirements
- Closed loop performance
- Define IO options
- Error terms inside and outside of the feedback loop
- Beam based calibration
- Multi-klystron regulation
- Sources of systematic errors
- Choice of IF and ADC sample rate

Simcon Diagram



Digital Control at the TTF





Cavity output envelope [MV]
Amplitude
flattop
filling
decay
In-phase
Quadrature
time [10^-6 s]
Controller output [mA]
Amplitude
In-phase
Quadrature
time [10^-6 s]
Phase of cavity and controller output [rad]
Controller
Cavity
time [10^-6 s]
Cavity detuning [Hz]
supposed detuning
estimated detuning
time [10^-6 s]

WG5 Specs

- The WG5 recommendations call for TESLA-like cavities to be used. They would be qualified to operate at a gradient of at least 35 MV/m with a $Q > 0.8\times10^{10}$ in CW tests (cavities not meeting these requirements would be rejected or reprocessed). Only a small fraction of the cavities and cryomodules would be pulsed-power tested. With such screening, they expect that a 31.5 MV/m gradient and Q of 1×10^{10} would be achieved on average in a linac made with eight-cavity cryomodules. This assumes that (1) the rf system would be capable of supporting 35 MV/m operation throughout the linac (2) some of the poorer performing cavities would be de-Q'ed so the associated cryomodule can run at a higher gradient and (3) the cryomodule power feeds would include attenuators so the average gradient in each unit can be maximized. For a future upgrade, they recommend that cavities of the low-loss or reentrant type be used and that they be qualified to at least 40 MV/m with $Q > 0.8\times10^{10}$ in order to achieve 36 MV/m and $Q = 1\times10^{10}$ on average in the linac.

RF Parameters

Parameter/ System	ILC	Proton Driver	CW
Uncorrelated Amplitude	0.08%, 0.03 deg	0.2%, 0.3 deg	0.01 %, 0.01 deg
Correlated	0.08%, 0.03 deg	0.03%, 0.1 deg	0.01 %, 0.01 deg
Bunch to Bunch Energy	0.05%		
Stored Energy W	144J/m	80.5J/m	
Gradient	35MV/m	26 MV/m	
Beam Current	9.5mA	8.3mA	
Uncorrelated / Klystron	0.08%?	0.1% ?	
Klystrons/Linac	286	12	
Cavities/Klystron	24	36 to 48	
Loaded Q	2.6E6	1.5E6	?E7

High Power RF

- Baseline

- The 10 MW Multi-Beam Klystrons (MBK's) being developed by Thales, CPI and Toshiba are the baseline choice. The basic tube design appears to be robust while alternative approaches have not been fully designed nor are currently funded to be developed. At worst, if the MBK's do not meet availability requirements, the commercial, single-beam, 5 MW tube from Thales could be used (it has been the 'work-horse' for L-band testing at DESY and FNAL). Although it is less efficient (42% vs 60-65%), this tube has been in service for over 30 years with good availability.

- Alternatives

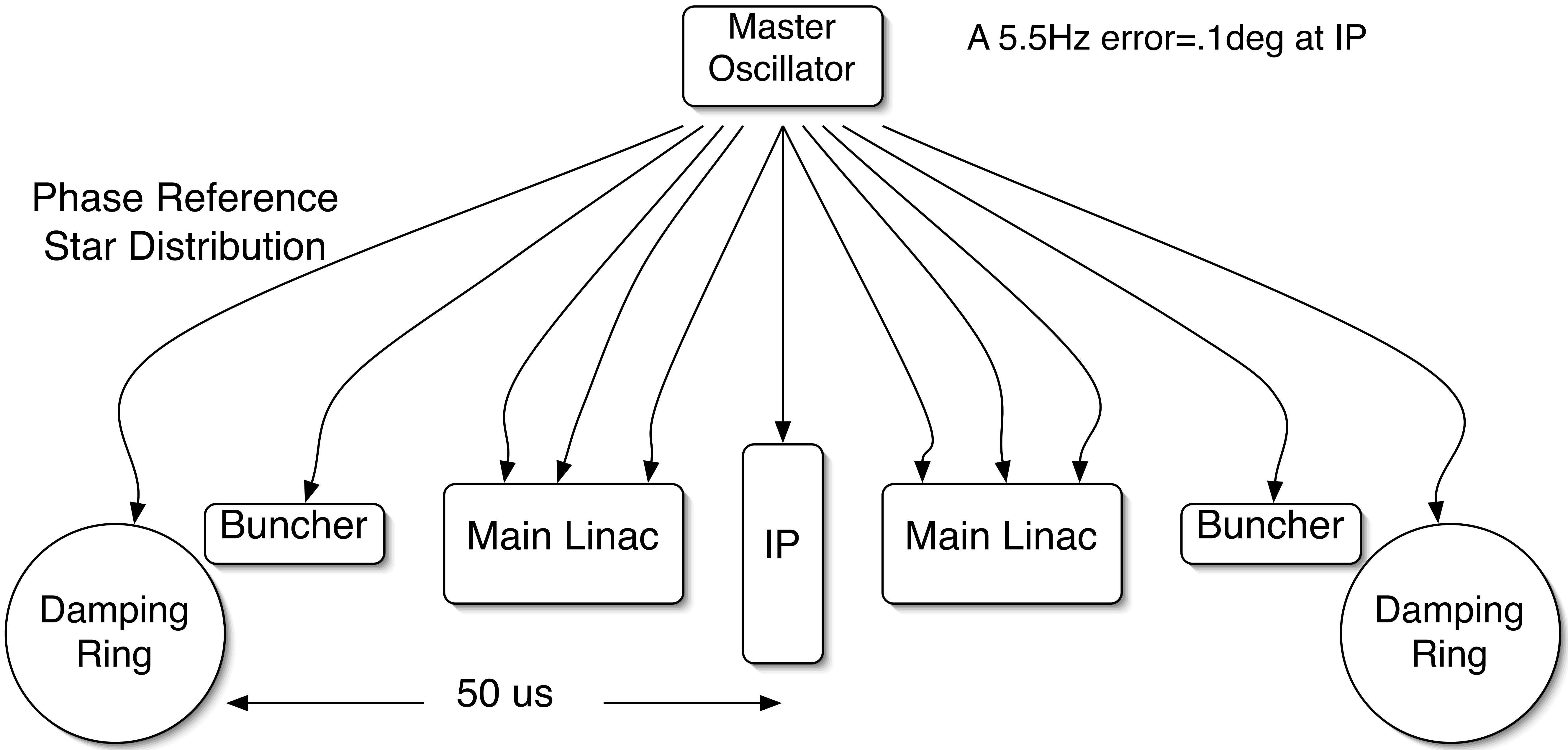
- The three alternatives discussed were a 10 MW Sheet-Beam Klystron (proposed by SLAC to reduce cost), a 5 MW Inductive Output Tube (proposed by CPI to improve efficiency) and a 10 MW, 12 beam MBK (proposed by KEK to reduce the modulator voltage, and the modulator plus klystron cost).

Buncher

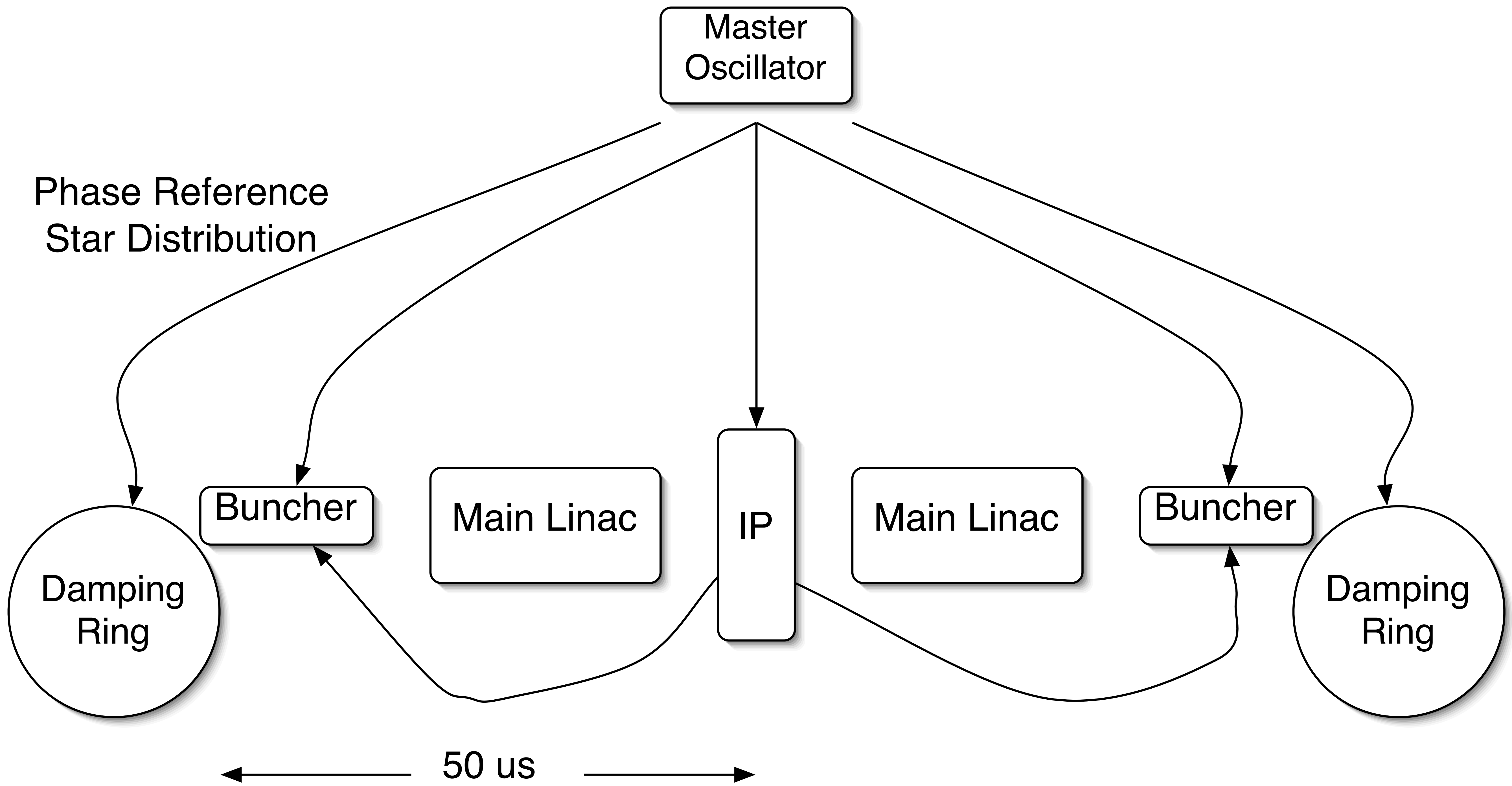
- Buncher is worst case
- Mixture of 0 and 90 deg beam loading
- Some systematic errors are alright if they are equal in both linacs

Limit Drive BW

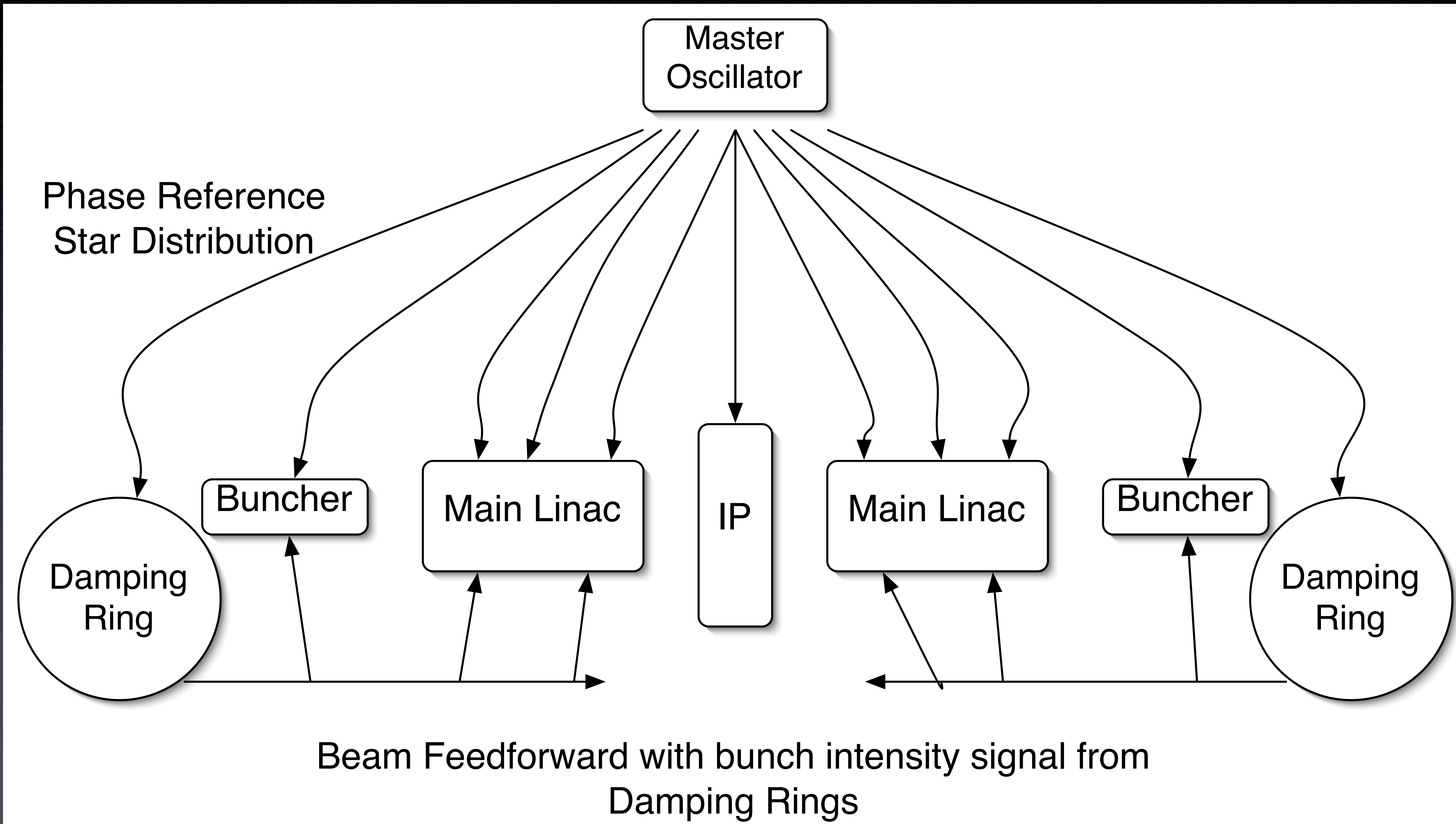
- Klystron has BW to drive other cavity modes
- These modes may not accelerate beam but will limit the max cavity field
- 1% power in other modes will reduce field by 10%

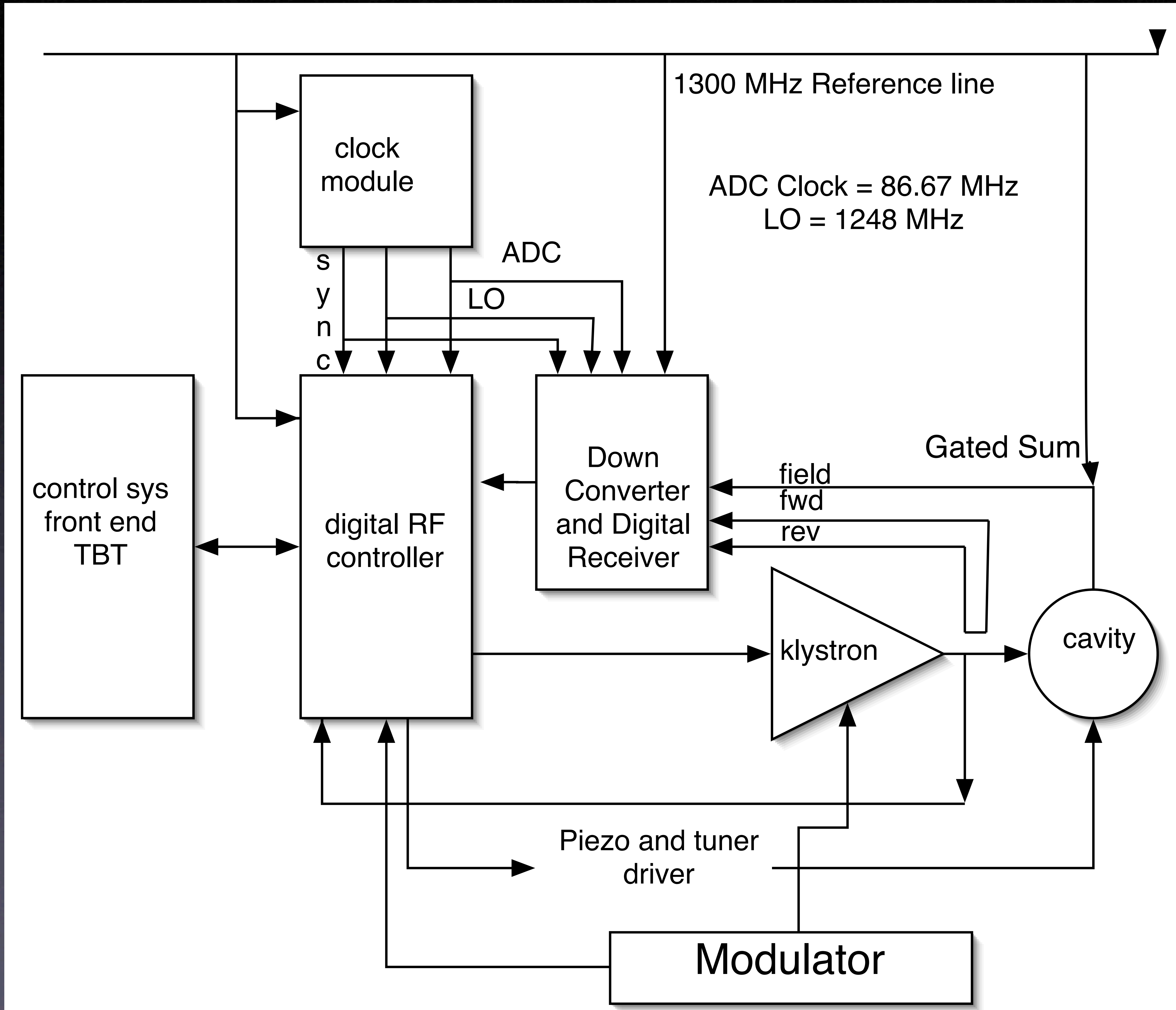


Symmetry - Small amounts of phase noise subtract out at the IP
Phase noise in star distribution or local reconstruction do not
0.1 degrees = 64 microns of ground motion - 4PPB

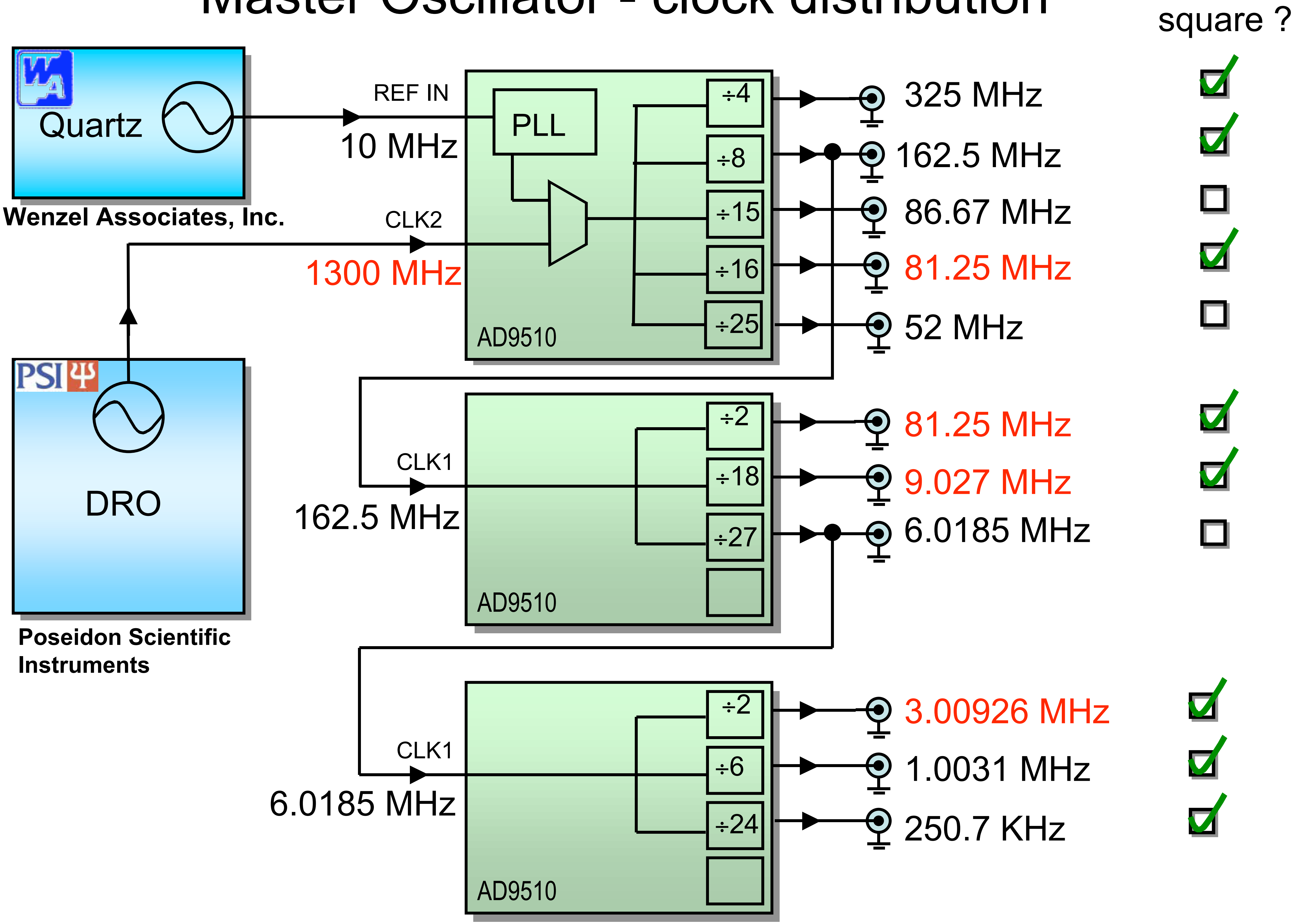


Symmetry - Reduce buncher phase noise by using a single fiber transmitter at the MO and also provide feedback from the IP

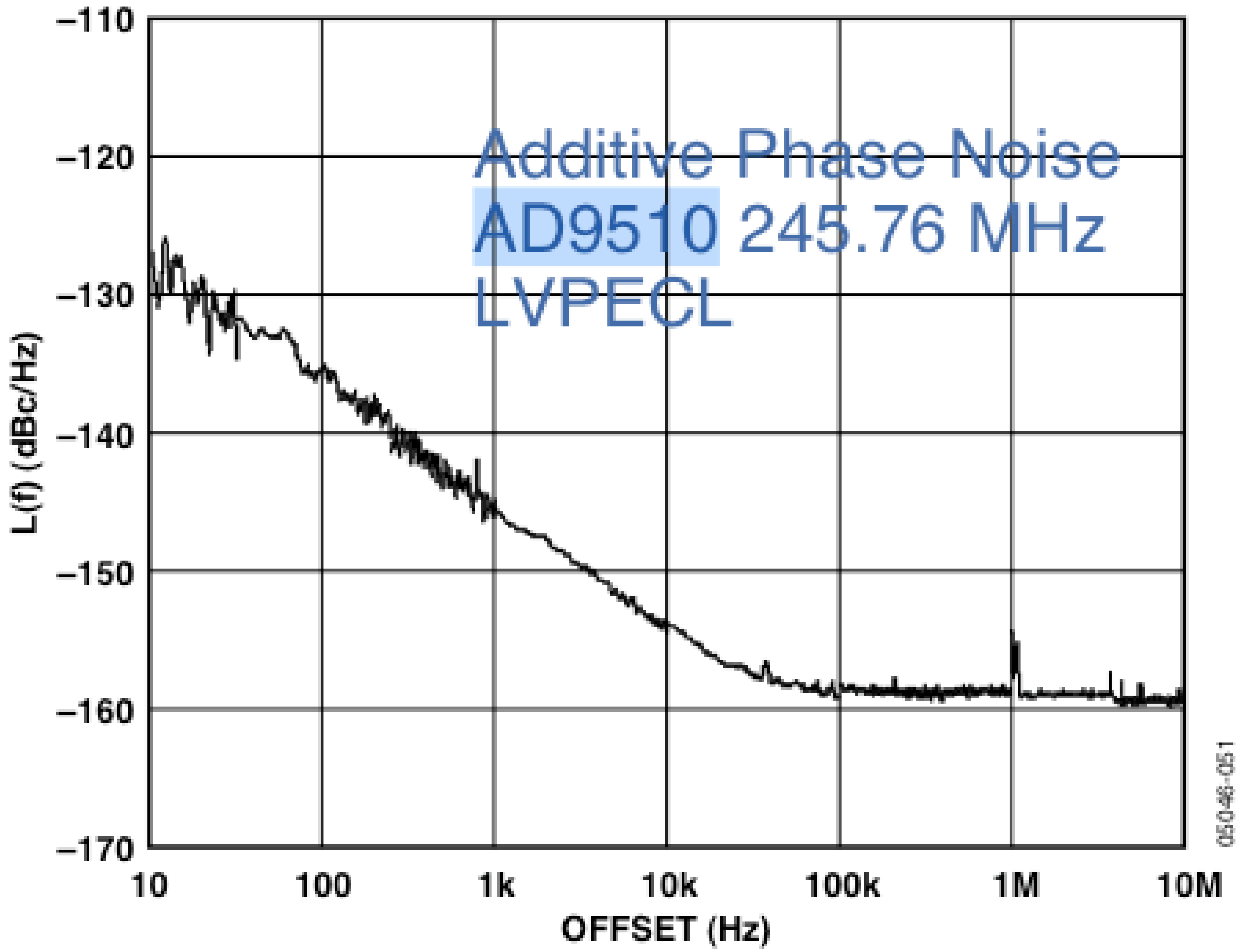

Master Oscillator
Phase Reference Star Distribution
Buncher
Main Linac
IP
Main Linac
Buncher
Damping Ring
Damping Ring
Beam Feedforward with bunch intensity signal from Damping Rings


1300 MHz Reference line
clock module
ADC Clock = 86.67 MHz
LO = 1248 MHz
ADC
LO
sync
control sys front end TBT
digital RF controller
Down Converter and Digital Receiver
Gated Sum
field
fwd
rev
klystron
cavity
Piezo and tuner driver
Modulator

Master Oscillator - clock distribution



Additive Phase Noise



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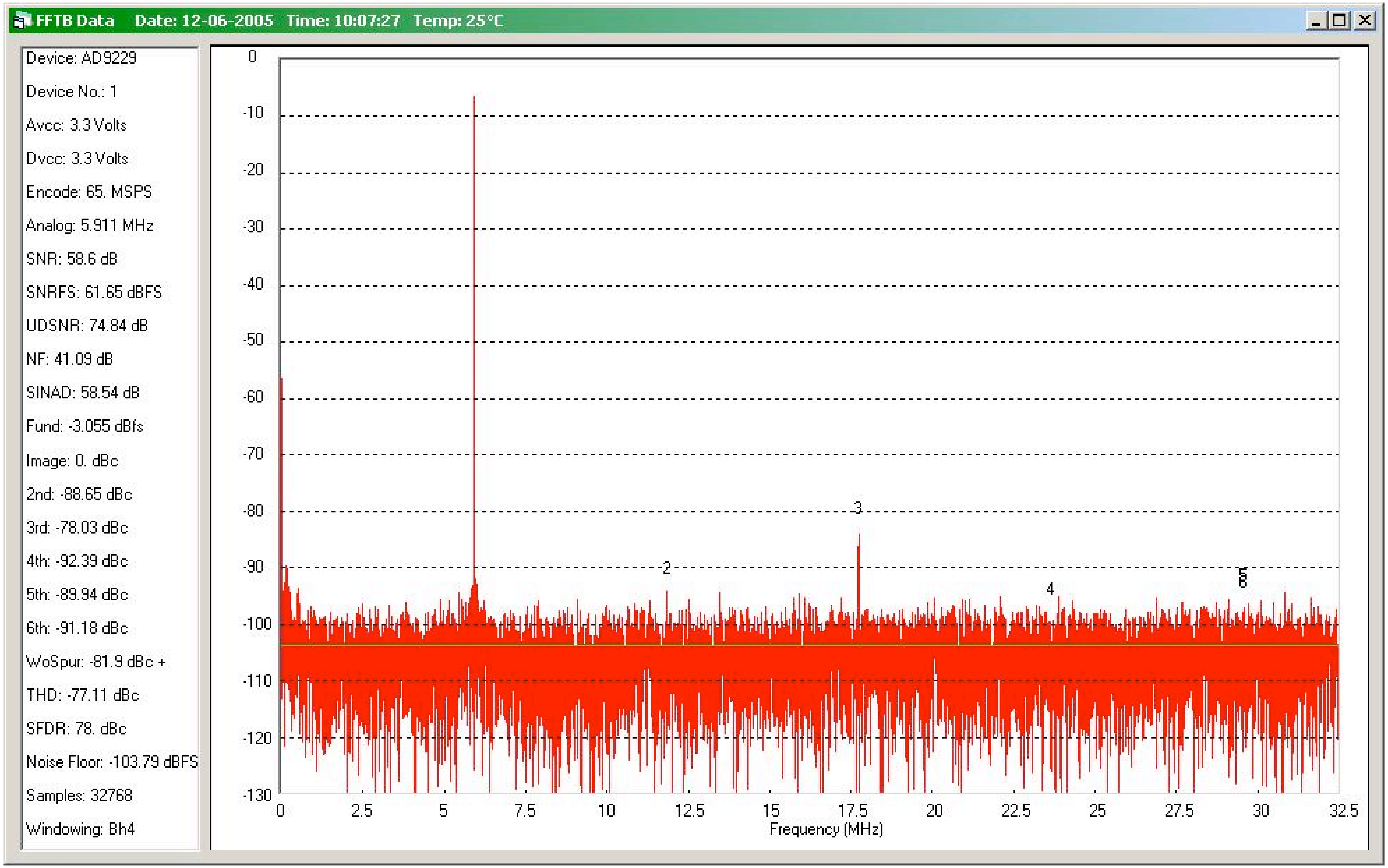
ANALOG DEVICES

F_{in} = 59.09 MHz, P_{in} = 16.0 dbm
(w/ 50 MHz input filter)



Advantages of IOTs

- Less Group Delay
- More linear at operating point
- Dynamic range overhead
- Much higher effiency 72% vs 50% at operating point
- Smaller, lighter, cheaper, longer life